PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Solid State Switching Arrangements

We, DANFOSS A/S, a Danish Company of Nordborg, Denmark, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to solid state switching arrangements including at least two junctionless non-rectifying semi-conductor switching devices.

According to the present invention a solid state switching arrangement consisting of at least two junctionless non-rectifying semiconductor switching devices is provided in which the electrodes of each device are separated by a single element of material having a polycrystalline structure and providing the switching portions of all the devices.

Such switching devices are symmetrical and may be switched from a high-resistance to a low-resistance condition by the application in either sense of an applied voltage or electric field at or above a threshold value. Certain types of these devices return to the high-resistance condition when the current returns to zero, but others have the property that they do not switch back, even though the current is reduced to zero or even reversed, until the application of a current or current pulse above a corresponding threshold value. Since the device is symmetrical, the switching current or current pulse may be either in the same or the opposite sense to that of the initial voltage pulse.

Unlike the monocrystalline layers of the well known types of multi-layer diodes, a polycrystalline switching device has the characteristic that it is not the whole switch that switches from the high-resistance to the low-resistance condition and back again, but only a path arising afresh on each single switch-on function. This path gets broader on an increasing strength of current, but nevertheless it retains a relatively small cross-sectional area. The material lying outside this current path therefore remains highly resistive and serves as an insulating resistance for the neighbouring switching devices.

Generally it is impossible to say where the path will go in each single case. It is known, however, that the path will be the shortest possible way between the two electrodes of the respective devices. Consequently it will generally only be necessary to arrange the electrodes in such a way that the current path, which may be expected to arise between two electrodes does not coincide with the current path to be expected between two other electrodes.

There are, however, exceptions where it might be advantageous to have two neighbouring pairs of electrodes spaced from one another by a distance comparable to the separation of two electrodes of the same pair. Such an arrangement is to be preferred when two neighbouring switching devices are required to influence one another.

Further, according to the invention the switching arrangement comprises a layer of polycrystalline structure on a supporting element and is covered on both sides by electrodes, at least two electrodes on the same side being spaced from one another. In this case the supporting element may be electrically conducting and serve as a joint electrode for all the switching devices included in the arrangement. Such a device is, for instance, very easily produced by vaporising the layer of solid state switch material and the electrodes on to the supporting element. Flame spraying, electrolytic separation and the cathodic evaporation can in this connection be considered as methods of forming the switching device.

In another embodiment of the invention

[*Price* 4*s*. 6*d*.]

the electrodes are of strip-like form and placed on each side of the switching arrangement in parallel groups, those on one side of the arrangement lying at right angles to those on the other side. Thus a grating of switching devices is formed in which each single device may be defined as a combination of a strip electrode from one side of the grating and another strip electrode from the other side of the grating. Such an arrangement is very suitable for electrical switch connections of a store.

According to another method of forming the solid state switching arrangement of the invention, the layer of polycrystalline structure is obtained by solidification of a molten alloy, the electrodes being kept in contact with the molten alloy.

Of particular interest in this connection is the use of switching devices which consist predominantly of tellurium with the addition of elements from Groups IV and V of the Periodic Table. These are for instance polycrystalline, absolutely symmetrical solid state switches, which can carry high loads and are very easily manufactured. An example is a switching device produced from 67.5% tellurium, 25% arsenic, and 7.5% germanium. This can be produced by vaporisation on to a metal plate, by sintering, by allowing a molten alloy to solidify, or by similar treatments.

Switching devices of this composition switch to the low-resistance condition when a control voltage of sufficient strength is applied, and switch back to the high-resistance condition when the current returns substantially to zero. There are, however, switching devices of a similar nature which do not return to the high-resistance condition when the current returns to zero, but remain in the low-resistance condition until the application of a current or current pulse above a threshold value. The current or current pulse may be in the same or in the opposite sense to that of the original voltage pulse. Such memory elements may, for instance, consist predominantly of tellurium and one element from Group IV of the Periodic Table. An example of such, would be a mixture of 90% tellurium and 10% germanium.

Various embodiments of the invention will now be described more fully, by way of example, with reference to the accompanying drawings in which:—

Fig. 1 shows a first embodiment of the invention with three switching devices and four electrodes,

Fig. 2 shows a second embodiment of the invention with three electrodes,

Fig. 3 shows a third embodiment of the invention with two solid state switches and four electrodes,

Fig. 4 shows a cross-sectional cut through grating of a switching arrangement, and

Fig. 5 shows a drawing of fig. 4 after removal of the insulating protective cover.

In fig. 1 a metal plate 1 is provided with a layer 2 of polycrystalline material which provides the switching portions or three junctionless non-rectifying semi-conductor switching devices. On the layer three electrodes 3, 4 and 5 are placed. On the application of voltage which exceeds the threshold value between the plate 1 and one of the electrodes 3 to 5, the current path can in each case only arise in the areas 6, 7 and 8, i.e. under the electrodes 3 to 5. The rest of the layer 2 remains high-ohmic. One may therefore imagine two dividing lines 9 and 10 drawn whereby the layer 2 is divided into the three switching devices 11, 12 and 13, each separated from one another.

In fig. 2 a conducting plate 14 is likewise provided with a layer 15 of a polycrystalline solid state switch material. Over this an electrode layer 16 is spread which is divided by the dividing line 17 into two electrode parts 16*a* and 16*b*. If a voltage is applied to the electrodes 14 and 16*a* then a current path will arise in or near the area 18, probably on account of either a field strength concentration on the right edge of the electrode layer 16*a* or the disturbance of uniformity of the layer 15 as the dividing line 17 was scratched into it. As the distance between the two electrode parts 16*a* and 16*b* is shorter than that between the electrode 16*b* and the plate 14, the distance between the electrode part 16*b* and the conducting current path 18 is also shorter than that between the electrodes 16*b* and 14. Thus a voltage may be applied to the electrodes 16*b* and 14 which lies below the threshold value of the layer but is strong enough to cause a switch-function in the area of the layer which has been reduced by the current path 18. Thus, by applying a control voltage of the threshold value between the electrodes 16*a* and 14, a main circuit may be connected to the electrodes 16*b* and 14 even though it is operating at a voltage below the threshold value.

In fig. 2 the solid state polycrystalline layer 15 and the electrode layer 16 are vaporised on to the device. The layers may be very thin and of the order of microns.

Fig. 3 shows a switch arrangement 19 of solid state polycrystalline material which is produced by a solidification of a molten alloy. In the molten alloy four electrodes 20, 21, 22 and 23 are hung, which are fastened integrally with the switch on the solidification of the alloy. Assuming that the electrodes 20 and 21 belong to one system and the electrodes 22 and 23 to another, a conducting path can only arise in the areas 24 and 25, so that in spite of the uniform construction the two solid state switches are well separated from one another.

In the embodiment of the invention shown in fig. 4 an insulator 26 is provided with re-

cesses for the electrode bands 27. Over this is spread a layer 28 of solid state polycrystalline material, over which several parallel conductors 29 are placed in an insulating cover 30. The group of conductors 27 lies vertically under the group of conductors 29. Supposing a voltage lying above the threshold value of the layer 28 is applied to the two conductors marked with two arrows in fig. 5, then there will be an area 31 between the two electodes where a conducting current path may arise. The areas 31 are separated from each other by material which remains permanently in a high-resistance condition.

WHAT WE CLAIM IS:—

1. A solid state switching arrangement consisting of at least two junctionless non-rectifying semi-conductor switching devices, in which the electrodes of each device are separated by a single element of material having a polycrystalline structure and providing the switching portions of all the devices.

2. An arrangement according to claim 1, which comprises a layer of polycrystalline structure on a supporting element, and is covered on both sides by electrodes, at least two electrodes on the same side being spaced from one another.

3. An arrangement according to claim 2, in which the supporting element is electrically conducting and serves as a joint electrode for all the switching devices included in the arrangement.

4. An arrangement according to claim 1 or 2, in which the electrodes are of strip-like form and placed on each side thereof in parallel groups, those on one side of the arrangement lying at right angles to those on the other side of the arrangement.

5. An arrangement according to any one of the claims 1 to 4, in which the spacing between two neighbouring electrodes corresponds to the distance between their respective pairs on the other side of the arrangement.

6. A method of forming the arrangement according to any one of the claims 1 to 5, including the step of forming both the layer of polycrystalline structure and the electrodes by vapour deposition.

7. A method of forming the arrangement according to claim 1, in which the layer of polycrystalline structure is obtained by solidification of a molten alloy, the electrodes being kept in contact with the molten alloy.

8. A method according to either of claims 6 or 7, in which the element of polycrystalline structure predominantly consists of tellurium with the addition of elements from Group IV and V of the Periodic Table.

9. A method according to either of claims 6 or 7, in which the element of polycrystalline structure predominantly consists of tellurium and an element from Group IV of the Periodic Table.

10. A solid state switching arrangement substantially as herein described with reference to the accompanying drawings.

11. A method of forming a solid state switching arrangement substantially as herein described with reference to the accompanying drawings.

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1083154 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

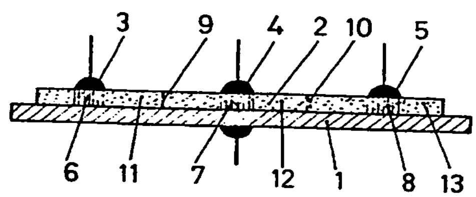

Fig. 1

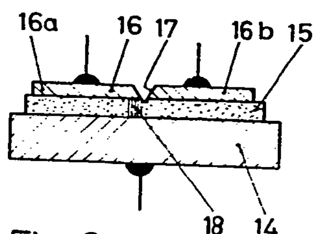

Fig. 2

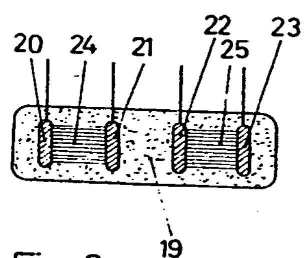

Fig. 3

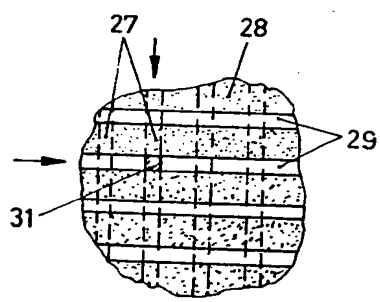

Fig. 5

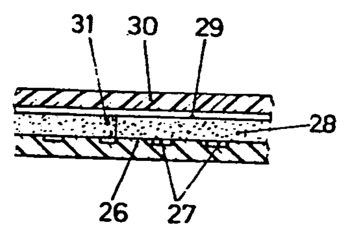

Fig. 4